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RES URBIS –– Resources from Urban Biowaste
Interim Financial and Technical Report

1.Summary for publication

1.1 Summary of the context and overall objectives of the project

Considering the strong EU commitment towards full implementation of an European circular economy, RES URBIS aimed at converting several types of urban organic waste into valuable bio-based products, in an integrated biorefinery.

Urban organic waste includes the organic fraction of municipal solid waste, excess sludge from urban wastewater treatment, garden and park waste, and selected waste from food-processing. Bio-based products include a biodegradable biopolymer (polyhydroxyalkanoate, PHA) and related PHA-based bioplastics as well as biosolvents (to be used in PHA extraction) and fibers (to be used for PHA biocomposites).

The technical goal of converting organic waste into these bioproducts has been combined to territorial and economic analyses, made with reference to several territorial clusters and especially considering the integration in the new waste-based biorefinery of existing anaerobic digestion plants. The market analysis was based on a portfolio of PHA-based bioplastics, which were tested for many uses.

A graphical sketch of RES URBIS concept is shown in Figure 1

1.2 Work performed from the beginning of the project to the end of the project and main results achieved.

During the whole project the following main results were achieved:

- **Long-term PHA production is feasible at pilot scale, starting from true organic waste:** Two pilot plants were continuously operated to produce PHA. One plant was fed with fruit processing effluents and the other one with a mixture of organic fraction of municipal solid waste and excess sludge from urban wastewater treatment. In both plants, the PHBV copolymer (3-hydroxybutyric and 3-hydroxyvaleric monomers) was produced, with HV content ranging between 10-20% w/w, depending on feedstock composition and operating conditions. In parallel, the key upstream step, i.e. production and concentration of PHA precursors (volatile fatty acids) has been improved.
- **3 generations of batches of PHA-containing biomass were prepared (PHA > 30 kg) for PHA extraction and downstream processing.** A set of different extraction methods was investigated using environmentally friendly inorganic reagents or organic solvents (including biosolvents generated in the project). The former was developed up to pilot scale. PHA with more than 95% purity was obtained, using reduced reagent quantities compared to initial protocols. The polymer remains white after melting test.
- **PHA applications.** PHBV-biomass samples were successfully extracted, processed through electrospinning, and characterised (mechanical and barrier properties) in comparison to commercial PHBV. In this way, applications as interlayer film, and “adjacent” adhesive market, have shown high market potential. Also, PHA was compounded and used for commodity films and durable goods, 90% bio-based and with acceptable mechanical properties. Biocomposite with fibres from park/garden waste were also developed as well as PHA-rich biomass was successfully tested as C-releasing material for groundwater remediation.
- **Presence of microcontaminants:** Polycyclic aromatic hydrocarbons (PAHs), polychlorobiphenyls (PCBs) and heavy metals, were analysed in raw materials (PHA-rich biomass) and in extracted PHA samples (by

using many extraction methods). Overall, it was shown that contaminant concentration meets present regulatory standards for several plastic applications.

- **The regulatory framework was analysed and drivers/barriers individuated.** The EU regulation on waste sector has recently been updated to conform to new challenges of the circular economy. The new regulation opens good perspective for RES URBIS value chain, provided that "end of waste" criteria are defined at least at national level. A draft dossier was defined in this direction. Also, it was found that being polymers, PHA are exempted from REACH and ECHA registration, unless impurities are more than 2% and their composition is not known.
- **The waste/sludge management systems of 5 territorial clusters was analysed** and data supplied for technical economic analysis of new scenarios according to the RES URBIS value chain.
- **A business model was defined**. For each territorial cluster, integration with existing AD plants to fit needs for biowaste treatment by 2024 was considered and overall potential for PHA production of around 7 kton/year was estimated, along with additional bio-waste treatment of 270 kton and over 6 million m^3 additional biogas generated. The opportunity for replication was projected for whole clusters (30 kton/year) and at European level (80-100 sites).
- **A complete LCA was performed** that compared 6 potential scenarios for the management of urban organic waste, where the baseline was current management. The LCA was largely built on data collected and generated within the project, e.g the calculations made to extrapolate an inventory of a full-scale version of the RES URBIS biorefinery. The results showed that the RES URBIS biorefinery has potential environmental benefits.
- **Work health and safety** aspects were also positively checked as for biological, chemical and explosion risks.
- **Social perception was investigated** through questionnaires that explored drivers and barriers to consumers' awareness and acceptance of waste-based bioproducts and what would drive the decision to switch from traditional to these new products. In particular, data from UK, Poland, Germany, Italy, Spain + USA panels showed a general consumer acceptance of these products. There is a consumer convergence on products like bin or shopping bags.
- **A Stakeholder Platform met regularly.** The SP included 64 members, from 13 countries, including associations and clusters, reaching out to a wide number of associates. Through physical meetings and a questionnaire, SP helped us to understand the challenges (economic and practical) faced in the use of wastes to produce bioplastics; in the use of bioplastics in packaging; and in the end of life of such materials once discarded.
- **The strategic roadmap for implementation of RES URBIS** and for upscale at industrial level was defined. It includes strategic scenarios based on the interest of the territorial clusters in becoming early adopters of the RES URBIS approach. The realization of a demo-scale plant is considered a key step for RES URBIS deployment.
- **An intense dissemination activity was made for technical and non-technical audience.** For more info the RES URBIS website can be visited at: www.resurbis.eu

1.3 Progress beyond the state of the art, expected results until the end of the project and potential impacts (including the socio-economic impact and the wider societal implications of the project so far)

In conclusion, at the end of the project, we demonstrated (at TRL 6) the whole RES URBIS technology chain to convert urban organic waste into PHA-based bioplastics, by taking care of all technical and non-technical aspects (figure 2). The value chain was shown to be flexible enough to cope with different waste management systems, to be easily integrated with existing anaerobic digestion plants, and to offer economic gain while maintaining PHA at an affordable price for the tested product portfolio (3 €/kg). Provided that an intermediate demo-scale action is performed, the RES URBIS value chain could affect most waste management systems for territorial clusters of more than 500.000 inhabitants (where more than 340 million European live in).

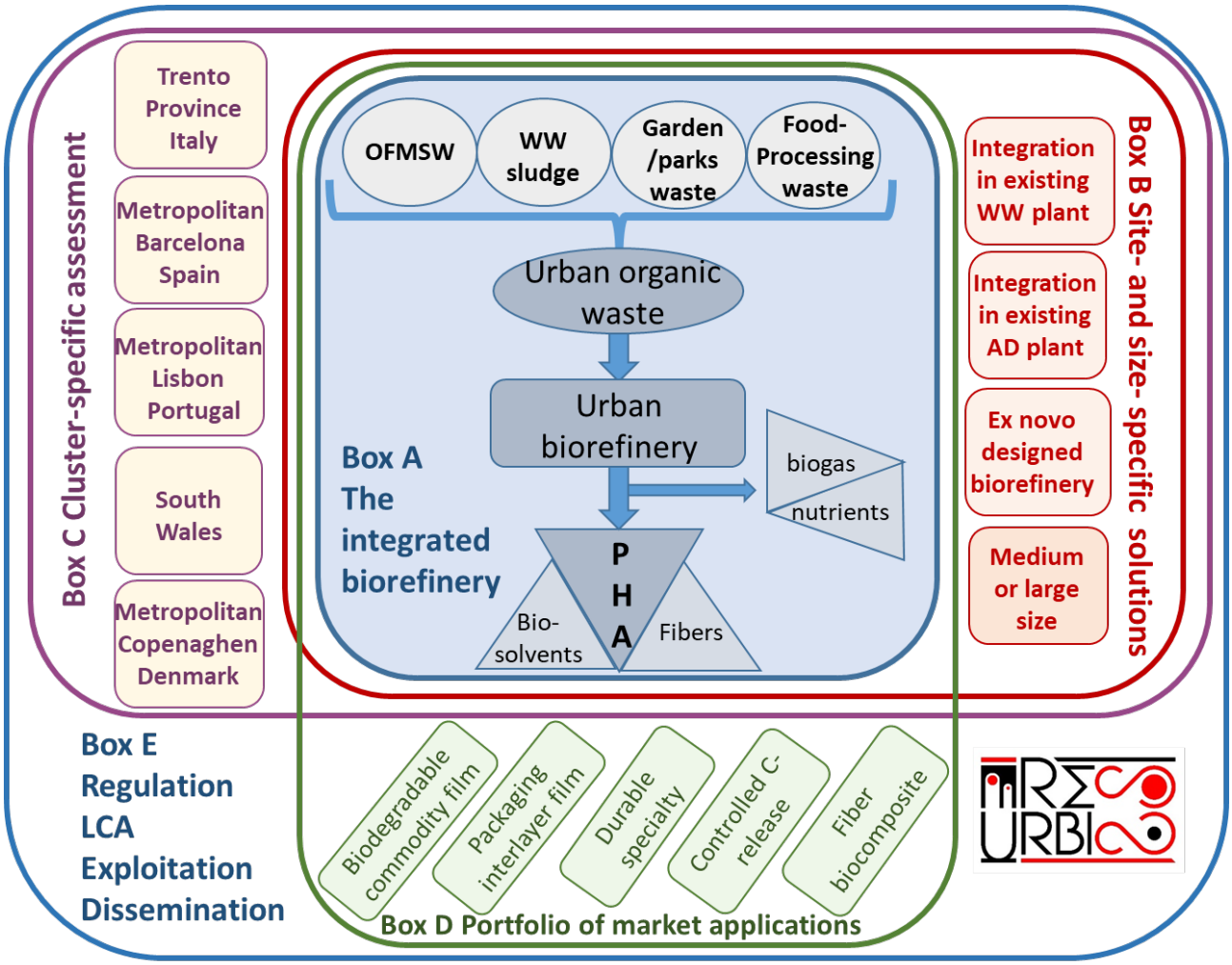

Figure 1 The RES URBIS box-model

Question	Answer	Comments
Is the PHA production from organic waste technically feasible?	Yes	At pilot scale, and robust enough
Can the PHA production be integrated with existing waste treatment plants?	Yes	Retrofitting of plants for increasing their capacity
Is the PHA production from organic waste economically affordable?	Yes	At a cost of 3 €/kg and even less in favourable conditions
Is the PHA production from organic waste environmentally sustainable?	Yes	Based on LCA, negative enviromental burden
Is the PHA production from organic waste acceptable in a consumer perspective?	Yes	Good willingness to purchase
Can the PHA production from organic waste be implemented under present regulation?	Yes	But «end of waste» criteria to be defined yet
Is PHA production from organic waste well aligned to European policy (i.e. Circular Economy Package, European Plastic Strategy)?	Yes	Policies for biodegradable plastic and sludge management to be better defined
Is the produced PHA suitable for intended applications?	Yes	Potential for replacing oil-based plastics, but not of general purpose
Does a market exist for PHA from organic waste?	Yes	High potential for selected applications

Figure 2 RES URBIS at a glance